Price level targeting, the zero bound on the nominal interest rate and imperfect credibility*

Gino Cateau, José Dorich†

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Abstract

The recent episodes of near zero nominal interest rates and the ensuing economic meltdown in economies with implicit or explicit inflation targeting (IT) regimes have raised questions about the effectiveness of IT as a monetary policy framework. In this respect, given its better ability to influence inflation expectations, price level targeting (PLT) has recently emerged as a potentially superior approach to monetary policy than IT. In this paper, we analyze whether a transition from IT to PLT is welfare improving when the zero lower bound constraint on the nominal interest rate can occasionally bind and agents take time to fully adopt PLT in forming expectations. We find that accounting for the ZLB significantly increases the gains from adopting PLT. However, these gains can be offset very fast when agents take time to fully believe in PLT.

Keywords: Price-level targeting; Inflation Targeting; Nonlinear optimal policy; Liquidity Trap

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*Opinions expressed in this paper are those of the authors and do not necessarily reflect those of the Bank of Canada or its staff. Any remaining errors are ours.

†Bank of Canada.

1 Introduction

In the aftermath of the recent financial crisis, central banks in many advanced economies lowered their policy interest rates to record lows and resorted to unconventional monetary tools to counter rapidly deteriorating economic outlooks. In the ensuing global recession, millions of jobs were lost; trillions of dollars of output foregone. These zero lower bound episodes and the large welfare costs associated with them have called into question the effectiveness of our existing monetary policy frameworks and have given new impetus to the quest for monetary policy frameworks that can achieve price stability while at the same time provide enough flexibility to deal with the zero lower bound constraint on nominal interest rates. To that effect, price level targeting (PLT) has recently emerged as a potentially superior approach to monetary policy than inflation targeting (IT).

There is one main reason why PLT can in theory be more effective than IT in dealing with the ZLB constraint: under PLT, inflation expectations can automatically adjust to stabilize the economy. To see why, suppose that an unanticipated shock pushes the price level below target. Under PLT, private agents will expect higher than average inflation in the near future since, under a credible PLT regime, they understand that the central bank will need to engineer a period of higher than average inflation to bring the price level back to target. This ability of expectations to act as automatic stabilizers gives PLT two advantages over IT in dealing with the ZLB constraint. First, the fact that inflation expectations can automatically adjust to stabilize the economy means that there is less of a need for the central bank to move interest rates aggressively in response to shocks (Cover and Pecorino 2005). Other things equal, less aggressive interest rates paths reduce the likelihood that interest rates will hit the ZLB constraint in the first place. Second, the ability of PLT to generate positive inflation expectations in a deflationary situation can lower real interest rates even when the nominal interest rate is at zero. Thus even when the nominal interest rate is at zero and cannot be reduced any further, the ability of expectations to adjust under PLT can generate the lower real rates required to give the economy a further boost.

The superiority of PLT in dealing with the ZLB constraint on nominal interest rates is, in fact, well known in the literature. Using the standard New Keynesian model, Eggertson and Woodford (2003) show that the optimal commitment policy at the ZLB can be implemented through a form of credible commitment to PLT. Moreover, Coibion, Gorodnichenko, and Wieland (2010) show that a credible PLT regime delivers large welfare gains by reducing both the likelihood and the duration of the ZLB episodes.[1] Given those benefits of PLT, should IT central banks switch

[1]Other studies that support the adoption of PLT are Wolman(2005), Vestin (2006), Nakov (2008) and Dib et al (2008). Wolman (2005) and Nakov (2008) consider the ZLB constraint on nominal interest rates in their analysis whereas the other two studies do not.

to PLT?

There is one important consideration to investigate in answering the above question. Most of the literature that evaluates the benefits of PLT relative to IT assume that a PLT regime will be fully credible. The latter assumption means that private agents believe that the central bank is committed to PLT, instantaneously understand the implications of this regime and form their expectations accordingly. This assumption, however, may be particularly weak during the transition to a new policy regime since it is not unreasonable to think that private agents may take time to adjust their behavior. Walsh (2010), for instance, points out that upon the introduction of IT regimes in the 1990s,"credibility followed experience and the gain in anchoring expectations was not something that was achieved immediately". Should the public doubt or take time in believing in the central bank's ability or commitment to return prices to the target path, expectations will have more difficulties to serve as automatic stabilizers. It is not clear in that instance whether PLT can still be effective as a tool to deal with the ZLB constraint on nominal interest rates.

In this paper, we analyze whether it would be welfare improving for an IT central bank to switch to a PLT regime if the ZLB constraint on the nominal interest rate can occasionally bind and agents take time to fully adopt price level targeting in forming expectations. As in Vestin (2006), we consider an environment where the central bank operates under discretion[2] and is delegated either an inflation target or a price level target by a social planner.[3] We allow for imperfect credibility[4] by assuming that once the switch to PLT is made, private agents doubt that the policy-maker will implement the new regime. Specifically, they assign a positive probability weight to the event that the policy-maker will set policy according to inflation targeting in the following period. With time, this weight eventually reaches zero so that private agents expectations are fully consistent with price-level targeting. Finally, in order to account for the ZLB on nominal interest rates in a discretionary environment, we use the collocation method as described in Miranda and Fackler (2002) and Adam and Billi (2007).

We find several interesting results. First, PLT offers significantly better per-

[2]According to Clarida et al (1999), discretion accords better with reality than the full commitment case as no major central bank makes a binding commitment over the future path of its monetary policy.

[3]Vestin (2006), however, evaluates the relative performance of IT and PLT ignoring the existence of the ZLB constraint. Our paper extends Vestin's analysis by explicitly allowing the ZLB constraint in our analysis.

[4]Schambaurg and Tambalotti (2006) models imperfect credibility as a situation where private agents assign a probability to the event that a new policy-maker may renege on the promise of its predecessor and commit to a new policy plan. In contrast, we endow private agents with the benefit of doubt about a new policy regime by allowing them to assign a probability to the event that the policy-maker may have to revert to its previous policy regime.

formance than IT against the ZLB: (i) the frequency of hitting the ZLB under PLT is 4 times smaller than under IT, and (ii) when stuck at the ZLB, PLT engineers inflation expectations above target 52 percent more than under IT. Second, ignoring the existence of the ZLB underestimates the welfare gains of adopting a fully credible PLT by 60 percent. In fact, 37 percent of the welfare gains of a fully credible PLT result from its superior ability to deal with the ZLB. Third, the assumption that credibility in a PLT regime can be achieved fast is critical in realizing the gains from PLT. In our model, 3 quarters of imperfectly credibility are enough to outweigh the long run benefits of a fully credible PLT.

The paper is divided as follows. Section 2 presents the model. Section 3 presents the welfare gains of the transition from a fully credible IT to a fully credible PLT taking explicitly into account the existence of the ZLB constraint. Section 4 presents the welfare gains considering both an ocasionally binding ZLB constraint and imperfect credibility in the adoption of PLT. Section 5 concludes.

2 The Model

The following section contains four parts. In the first one, we presents a brief description of the core structure of the standard New Keynesian (NK) model frequently studied in the literature.[5]In the second one, we describe how credible IT and PLT regimes are modeled. In the third one, we explain how we model the switch from IT to PLT in the presence of imperfect credibility. Finally, we describe how we measure the social losses associated with each monetary policy regime.

2.1 The standard NK model: core structure

Inflation evolves according to the Phillips curve:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t \tag{1}$$

where π_t is inflation, $E_t\pi_{t+1}$ is expected inflation, x_t is the output gap and u_t is an exogenous cost push shock. The parameter β denotes the discount factor and $\kappa > 0$ is given by:

$$\kappa = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha} \frac{\sigma^{-1}+\omega}{1+\omega\phi} \tag{2}$$

with α denoting the probability that a firm cannot change its price in a given period, $\sigma > 0$ the household's inter-temporal elasticity of substitution, and $\omega > 0$ the elasticity of a firm's real marginal cost with respect to its own level of output.

[5]See Woodford (2003) for further details.

The aggregate demand equation has the following form:

$$x_t = E_t x_{t+1} - \sigma(i_t - E_t \pi_{t+1}) + g_t \tag{3}$$

where $E_t x_{t+1}$ is the expected output gap, i_t is the nominal interest rate and g_t is a shock that generates time variation in the natural real interest rate.[6]The shocks u_t and g_t are assumed to evolve according to AR(1) processes, as in Adam and Billi (2007). Thus,

$$u_t = \rho_u u_{t-1} + \varepsilon_t^u \tag{4}$$

$$g_t = \rho_g g_{t-1} + \varepsilon_t^g \tag{5}$$

where ε_t^u and ε_t^g are iid with zero mean and variances σ_u^2 and σ_g^2 respectively.

2.2 Modeling credible IT and PLT regimes

Following Vestin (2006), we assume that the objectives of monetary policy are delegated by the government to an otherwise independent central bank in the form of a loss function. In the case of inflation targeting, the loss function penalizes squared deviations of *inflation* and output gap:

$$E_t \sum_{i=0}^{\infty} \beta^i \{\pi_{t+i}^2 + \lambda^{IT} x_{t+i}^2\} \tag{6}$$

while under price level targeting, the loss function penalizes squared deviations of the *price level* and output gap:

$$E_t \sum_{i=0}^{\infty} \beta^i \{p_{t+i}^2 + \lambda^{PT} x_{t+i}^2\} \tag{7}$$

The weights λ^{IT} and λ^{PLT} are delegated by the government to minimize society's loss

$$E_t \sum_{i=0}^{\infty} \beta^i \{\pi_{t+i}^2 + \frac{\kappa}{\phi} x_{t+i}^2\} \tag{8}$$

Further, following Vestin (2006), we assume that the central bank acts under discretion i.e. cannot commit to future plans and hence sets policy on a period by period basis. Hence depending on whether the central bank is delegated an IT

[6]The natural real interest rate is defined as the real rate that would prevail if prices were completely flexible. Therefore, the shock g_t summarizes all shocks that can affect the real rate under fully flexible prices, like preference shocks, productivity shocks, etc.

or PLT loss function, the central sets policy by choosing $\{\pi_t, x_t, i_t\}$ to minimize either (6) or (7) subject to (1), (3), the ZLB constraint i_t

$$i_t \geq -r^* \tag{9}$$

and treating future values of y_t, π_t and i_t as given i.e.

$$\{y_{t+i}, \pi_{t+i}, i_{t+i}\} \text{ given for } i > 0 \tag{10}$$

2.3 Transition to PLT and imperfect credibility

We assume a central bank that initially follows an inflation targeting regime. At time 0, however, the central bank is assigned a new price level targeting objective. Upon announcing that it will change its policy framework from inflation to price level targeting, private agents in the economy doubt that the central bank will be implementing a price-level target in the foreseeable future. As a result, in forming expectations about the future, they assign a probability θ_t to the event that the central bank will implement inflation targeting in the following period. Thus, following the switch to price level targeting, expectations about next period inflation and output gap are given by respectively

$$E_t(\pi_{t+1}) = \theta_t E_t(\pi_{t+1}|PLT) + (1-\theta_t)E_t(\pi_{t+1}|IT) \tag{11}$$

and

$$E_t(x_{t+1}) = \theta_t E_t(x_{t+1}|PLT) + (1-\theta_t)E_t(x_{t+1}|IT). \tag{12}$$

For tractability, we assume that θ_t can take two possible values: a low credibility value where $\theta_t = \theta_L$ or a high credibility value where $\theta_t = \theta_H$ where $0 \leq \theta_L < \theta_H \leq 1$. Given a particular initial condition at the time of the switch, θ_t evolves according to a Markov chain over $\{\theta_L, \theta_H\}$ with transition matrix

$$\Sigma = \begin{bmatrix} p & 1-p \\ 1-q & q \end{bmatrix} \tag{13}$$

Throughout this paper, we assume that $\{\theta_L, \theta_H\} = \{0, 1\}$. Thus in any given period when forming expectations about the future, private agents either assign full weight to the event that the policy-maker sets policy under price-level targeting $\theta_t = \theta_H = 1$ or not at all $\theta_t = \theta_L = 0$. Further, we assume that $q = 1$ i.e. the high credibility state is an absorbing state. Thus private agents eventually converge to the high credibility state and thus eventually form expectations about the future consistently with a price level targeting objective. However, on average, it takes agents $\tau = \frac{1}{1-p}$ quarters to transit to the high credibility state θ_H and hence fully believe in PLT. How fast ϕ_t approaches 1 depends on the value p. The higher p is, the longer it takes for ϕ_t to be equal to 1.

2.4 Evaluating welfare

Credible IT and PLT, as well as an imperfectly credible PLT lead to different inflation and output gap dynamics. To evaluate the relative performance of these three alternatives, we measure welfare in units of steady state consumption. For the model at hand, this is given by

$$\frac{1}{2}\frac{\alpha\phi(1+\omega\phi)}{(1-\alpha)(1-\alpha\beta)}E_t\sum_{i=0}^{\infty}\beta^i L_{t+i} \tag{14}$$

where L_t is the society's period loss-function, (8), evaluated for the policy regime of interest.

3 Welfare Gains of Adopting PLT: Perfect credibility

In this section, we compute the welfare gains of the transition from IT to a fully credible PLT taking explicitly into account the existence of the ZLB constraint on nominal interest rates. To account for this constraint in the optimization problems, we use the collocation method as described in Miranda and Fackler (2002) and Adam and Billi (2007).

We calibrate the model to the U.S. economy following the baseline parameterization of Adam and Billi (2007) and as in Vestin (2006), we choose the weights λ^{IT} and λ^{PLT} to minimize society's loss (8). The parameter values are summarized in Table 1. For each regime, we simulate our model economy 5000 times and for 3000 periods. Table 2 presents various statistics from our simulations. Several interesting results emerge. First, whether we account for the ZLB or not, under perfect credibility PLT is superior to IT. The variance of inflation and output gap, and consequently, the social losses (measured in units of steady state consumption) are lower under PLT. However, PLT dominates IT much more significantly once we account for the ZLB. Indeed, the gains from adopting PLT are 60 percent higher once we account for the ZLB constraint and hence are underestimated in studies that do not account for it. Second, around 37 percent of the welfare gains of PLT arise from its better ability to deal with the ZLB. This can be explained by the fact that PLT dominates IT along two important margins: (i) It is more effective than IT in preventing the nominal interest rate from reaching the ZLB and avoiding the social costs associated with it. Indeed under PLT, the ZLB is reached 4 times less frequently than under IT, and (ii) In the event that the interest rate reaches the ZLB, the PLT regime manages to influence the real interest rate by generating above target inflation expectations. Indeed, PLT can engineer

Table 1: Parameter values (baseline calibration)

Parameter	Economic interpretation	Assigned value
β	quarterly discount factor	0.99
σ	real rate elasticity of output	6.25
α	probability of a firm not changing its price	0.66
ϕ	price elasticity of demand	7.66
ω	elasticity of firms'real marginal costs	0.47
κ	slope of the Phillips curve	0.024
λ	weight on output gap in the social loss function	0.0031
λ^{IT}	weight on output gap in the IT loss function	0.0031
λ^{PLT}	weight on output gap in the PLT loss function	0.0029
ρ_u	AR-coefficient mark-up shocks	0
ρ_g	AR-coefficient real rate shocks	0.8
σ_u	s.d. mark-up shock innovations (quarterly %)	0.154
σ_g	s.d. real rate shock innovations (quarterly %)	1.524

Table 2: IT versus PLT under perfect credibility

	No ZLB		ZLB	
	IT	PLT	IT	PLT
σ_π (*in* %)	0.13	0.11	0.14	0.11
σ_x (*in* %)	1.01	1.03	1.16	1.06
σ_i (*in* %)	0.436	0.404	0.446	0.404
Losses (*in* %)	0.0226	0.0176	0.0260	0.0180
$Pr(i_t = 0)$	–	–	0.026	0.007
$Pr(E_t\pi_{t+1} > 0 \mid i_t = 0)$	–	–	0.000	0.518

negative real interest rates at the ZLB 52 percent of the time whereas IT can never do so.[7] Therefore, by influencing real interest rates more effectively at the ZLB, PLT leads to lower inflation and output gap volatility, and lessens the social costs of operating at the lower bound.

[7]The fact that the real interest rate is never negative at the ZLB under IT reflects that this regime involves deflationary expectations at the ZLB. In contrast, PLT manages to generate inflation expectations, and therefore, engineers a negative real rate at the ZLB.

4 Welfare Gains of Adopting PLT: Imperfect credibility

In the previous section, we have shown that PLT leads to lower social losses than IT. Therefore, there are benefits of switching from IT to PLT in the long run. However, in order to obtain these benefits, it is typically assumed that economic agents fully understand the implications of PLT, believe that the central bank is committed to follow a PLT objective and hence can instantaneously adjust their behavior. As Walsh (2010) argues, however, this assumption may be particularly weak during a transition to a different policy regime. He points out that the experience with the adoption of IT in the 1990s was that credibility followed experience and the gain in anchoring expectations was not something that was achieved immediately. Therefore, it is not unreasonable to think that the adoption of PLT may also entail a transition period during which the credibility of the regime is built up. During this period, the ability of PLT to use expectations as automatic stabilizers would be negatively affected and hence may lead to some welfare costs. Can those welfare costs be large enough to justify not adopting PLT in the first place?

In this section, we explore if the transition costs associated with imperfect credibility at the beginning of PLT can outweigh the long-run benefits of this regime.[8]In particular, we analyze the transition from a credible IT to an imperfectly credible PLT.

In our model, the degree of credibility is determined by the transition probability, p, from the low credibility to the high credibility state. In the following experiment, we assume that agents are in the low credibility state for the first period and vary p between $0, 0.1$ and 0.5. With those values of p, it takes agents on average $1, 2.1$ and 3 quarters respectively to form expectations about the future consistent with a PLT objective.

Table 3 presents the results. We first find that the assumption that credibility can be achieved fast is critical in making a switch from IT to PLT worthwhile. In our model, 3 quarters of imperfect credibility in the PLT regime is enough to offset its long run benefits. This arises because when agents take time to fully adopt PLT, expectations cease to act as automatic stabilizers. As a result, the policy-maker needs to generate much more volatile movements in the output gap and interest rate to stabilize the economy. In turn, more volatile movements in the interest rates increase the likelihood of hitting the ZLB. Indeed, with three quarters of imperfect credibility, the ZLB is hit 3.6 per cent of the time under PLT whereas it is hit 2.6 per cent of the time under a credible IT regime. At the same

[8]Kryvtsov et al (2008) and Cateau et al (2008) evaluate the gains of switching from IT to an imperfectly credible PLT. However, both studies ignore the existence of the ZLB constraint.

Table 3: IT versus PLT with imperfect credibility

	IT	PLT			
T (*in quarters*)		0	1	2.1	3
σ_π (*in* %)	0.14	0.11	0.11	0.11	0.12
σ_x (*in* %)	1.16	1.06	1.06	1.25	2.11
σ_i (*in* %)	0.446	0.404	0.404	0.421	0.503
Losses (*in* %)	0.0260	0.0180	0.0181	0.0202	0.0313
$Pr(i_t = 0)$	0.026	0.007	0.007	0.011	0.036
$Pr(E_t\pi_{t+1} > 0 \| i_t = 0)$	0.000	0.518	0.518	0.331	0.070

time, the inability of expectations to adjust implies that it becomes more difficult for PLT to generate negative real interest rates at the ZLB. Indeed with three quarters of imperfect credibility, when the nominal interest rate is stuck at the ZLB, PLT can engineer above target inflation expectations only 7 per cent of the time as opposed to 52 percent when it is fully credible. Thus imperfect credibility severely affects the ability of PLT to stabilize inflation and output gap at the ZLB.

5 Concluding Remarks

In this paper, we have evaluated whether a transition from IT to PLT is welfare improving when the ZLB on the nominal interest rate is occasionally binding and agents take time to fully believe in PLT. Our quantitative results suggest that 3 quarters of imperfect credibility leads to transition costs that are big enough to outweigh the long run benefits of a fully credible PLT. This result underlines the idea that the net benefits of adopting PLT critically depends on its credibility.

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A Solving for the IT equilibrium under the ZLB

Recall that under a discretionary IT regime, a policy-maker chooses x_t, π_t, i_t to minimize

$$E_t \sum_{i=0}^{\infty} \beta^i \{\pi_{t+i}^2 + \lambda^{IT} x_{t+i}^2\} \tag{15}$$

subject to

$$\begin{aligned}
\pi_t &= \beta E_t \pi_{t+1} + \kappa x_t + u_t && (16)\\
x_t &= E_t x_{t+1} - \sigma(i_t - E_t \pi_{t+1}) + g_t && (17)\\
u_t &= \rho_u u_{t-1} + \varepsilon_t^u && (18)\\
g_t &= \rho_g g_{t-1} + \varepsilon_t^g && (19)\\
i_t &\geq -r^* && (20)
\end{aligned}$$

with $\{x_{t+i}, \pi_{t+i}, i_{t+i}\}$ given for $i > 0$.

Upon substituting (17) into (20), we derive the equilibrium conditions by solving the Bellman equation

$$V(u_t, g_t) = \min_{\{x_t, \pi_t\}} \left\{\pi_t^2 + \lambda^{IT} x_t^2 + \beta E_t V(u_{t+1}, g_{t+1})\right\} \tag{21}$$

subject to (16), (18), (19) and

$$\frac{E_t x_{t+1} - x_t + g_t}{\sigma} + E_t \pi_{t+1} \geq -r^* \tag{22}$$

and taking $\{x_{t+i}, \pi_{t+i}, i_{t+i}\}$ as given for $i > 0$.

Upon taking first order conditions and simplifying, the equilibrium conditions are:

If the ZLB does not bind

$$\begin{aligned}
\lambda^{IT} x_t &+ \kappa x_t = 0 && (23)\\
\pi_t &= \beta E_t \pi_{t+1} + \kappa x_t + u_t && (24)\\
i_t &= \frac{E_t x_{t+1} - x_t + g_t}{\sigma} + E_t \pi_{t+1} && (25)
\end{aligned}$$

If the ZLB binds

$$\begin{aligned}
\lambda^{IT} x_t &+ \kappa x_t < 0 && (26)\\
\pi_t &= \beta E_t \pi_{t+1} + \kappa x_t + u_t && (27)\\
i_t &= -r^* && (28)\\
x_t &= E_t x_{t+1} - \sigma(-r^* - E_t \pi_{t+1}) + g_t && (29)
\end{aligned}$$

We use the collocation method as described in Miranda and Fackler (2002) and Adam and Billi (2007) to solve for solution functions

$$
\begin{aligned}
\pi_t &= f_{\pi}^{IT}(u_t, g_t), && (30)\\
x_t &= f_{x}^{IT}(u_t, g_t), && (31)\\
i_t &= f_{i}^{IT}(u_t, g_t), && (32)\\
E_t\pi_{t+1} &= f_{E\pi}^{IT}(u_t, g_t), && (33)\\
E_t x_{t+1} &= f_{Ex}^{IT}(u_t, g_t), && (34)\\
& && (35)
\end{aligned}
$$

and where $f_{E\pi}^{IT}(u_t, g_t) = E_t f_{\pi}^{IT}(u_{t+1}, g_{t+1})$ and $f_{Ex}^{IT}(u_t, g_t) = E_t f_{x}^{IT}(u_{t+1}, g_{t+1})$